(12) UK Patent Application (19) GB (11) 2 335 554 (13) A

(21) Application No 9805596.5

(22) Date of Filing 18.03.1998

(71) Applicant(s)
Roke Manor Research Limited
(Incorporated in the United Kingdom)
Roke Manor, Old Salisbury Lane, ROMSEY,
Hampshire, SO51 0ZN, United Kingdom

(72) Inventor(s)
John Joseph Spicer

(74) Agent and/or Address for Service
Derek Allen
Siemens Group Services Limited, Intellectual
Property Department, Siemens House, Oldbury,
BRACKNELL, Berkshire, RG12 8FZ, United Kingdom

(51) INT CL^6
H03L 1/02 7/00

(52) UK CL (Edition Q)
H3A ALX AXX
U1S S2204 S2205 S2215

(56) Documents Cited
GB 2319912 A	GB 2313002 A	GB 2299225 A
GB 2273405 A	GB 2205460 A	WO 96/24986 A

(58) Field of Search
UK CL (Edition P) H3A AB ASX AXX , H4L LDLT , H4P
PAL
INT CL^6 H03J 7/02 7/04 , H03L 1/02 7/00
Online: EDOC WPI

(54) Abstract Title
Radio synchronisation system

(57) A radio synchronisation system for synchronising a receiver unit 3 with a radio signal comprises a local frequency reference 10 which operation to generate a local frequency reference signal which is used to initiate the synchronisation process, and a temperature sensing means 12 which operates to measure the temperature of the local frequency reference 10 and which further operates to communicate this information as a frequency offset Δf 28, such as, obtained from a mathematical model 18. The mathematical model 18 operates to improve the radio synchronisation process by providing frequency offset information to various functions within the radio synchronisation system. The frequency offset Δf 28 may be an analogue signal connected to the local frequency reference 10 or a digital signal connected to an aquisition and synchronisation unit 14 (Fig 5).
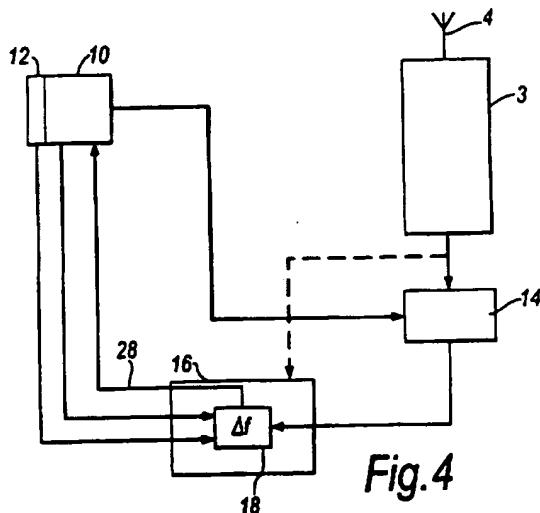

Fig.4

GB 2 335 554 A
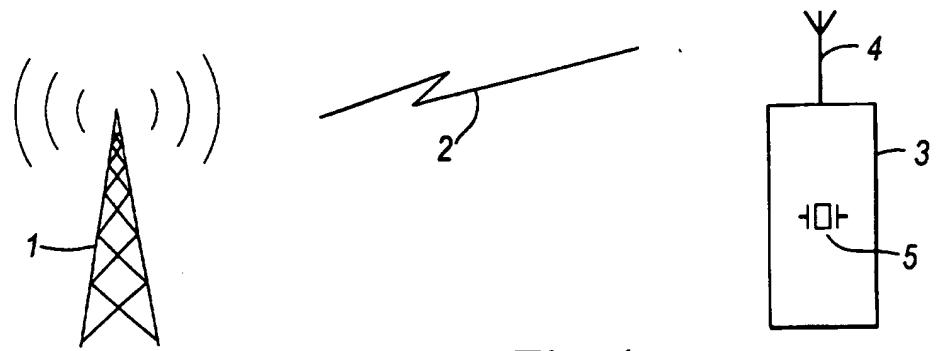
Fig.1
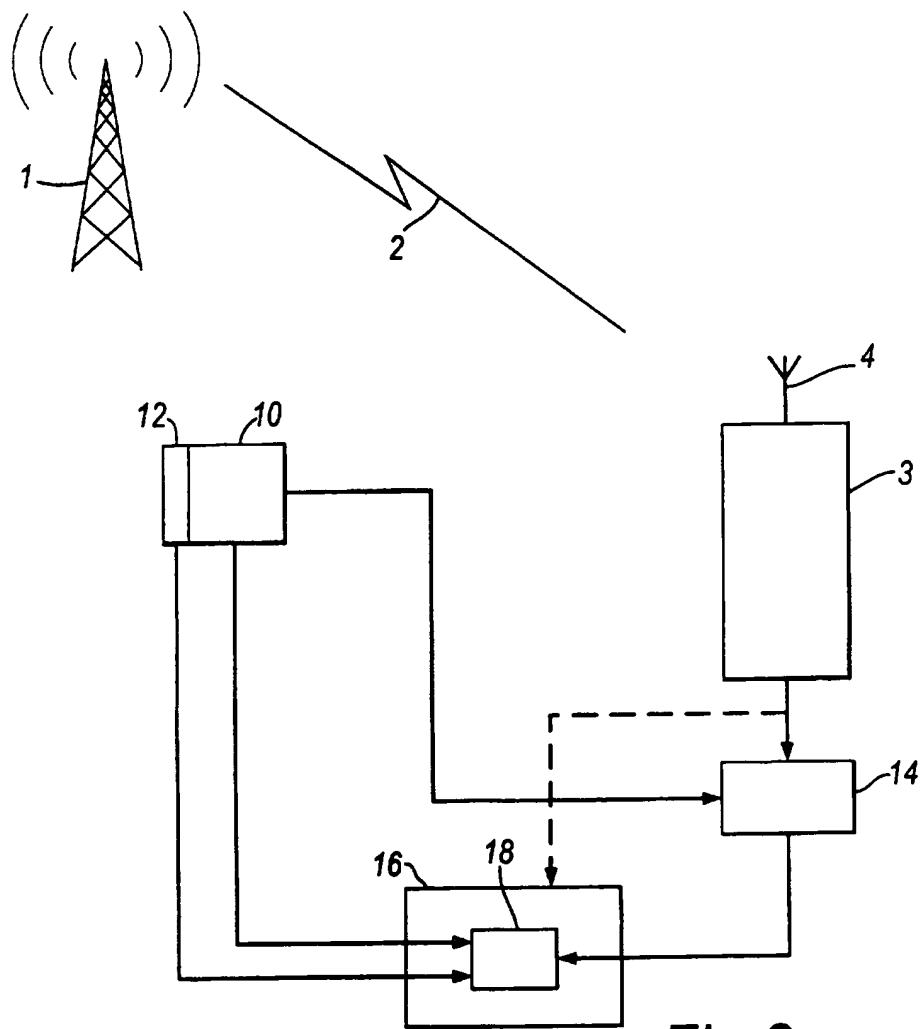
Fig.2
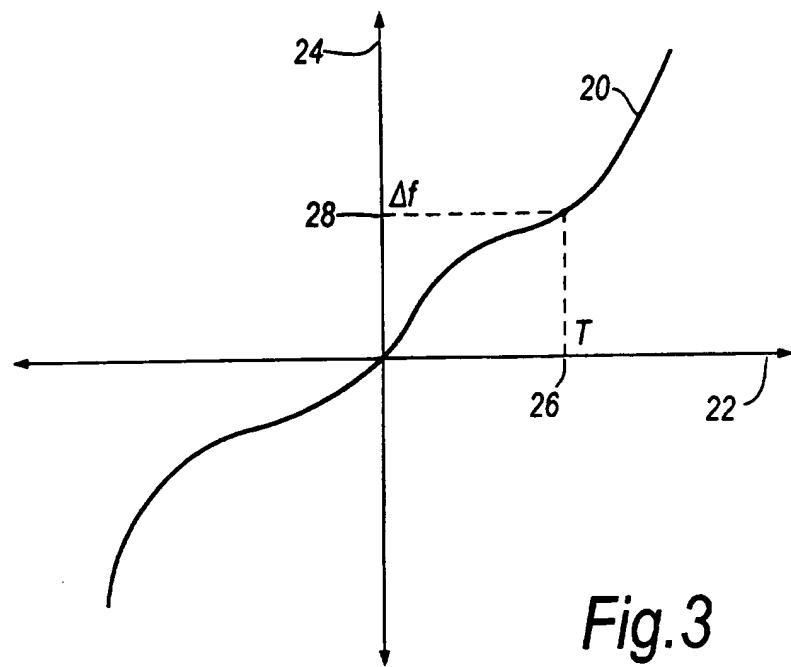
Fig.3
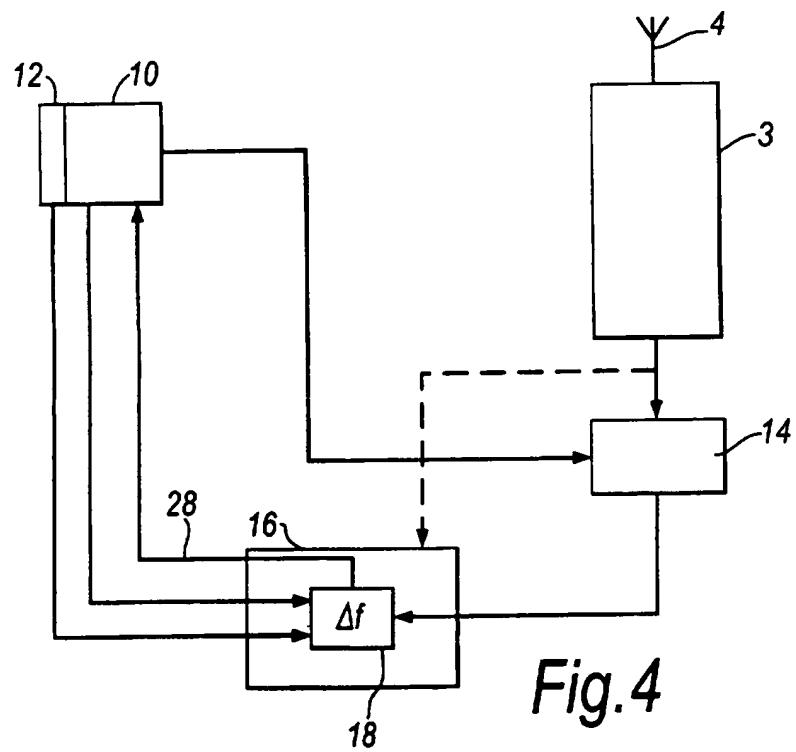
Fig.4
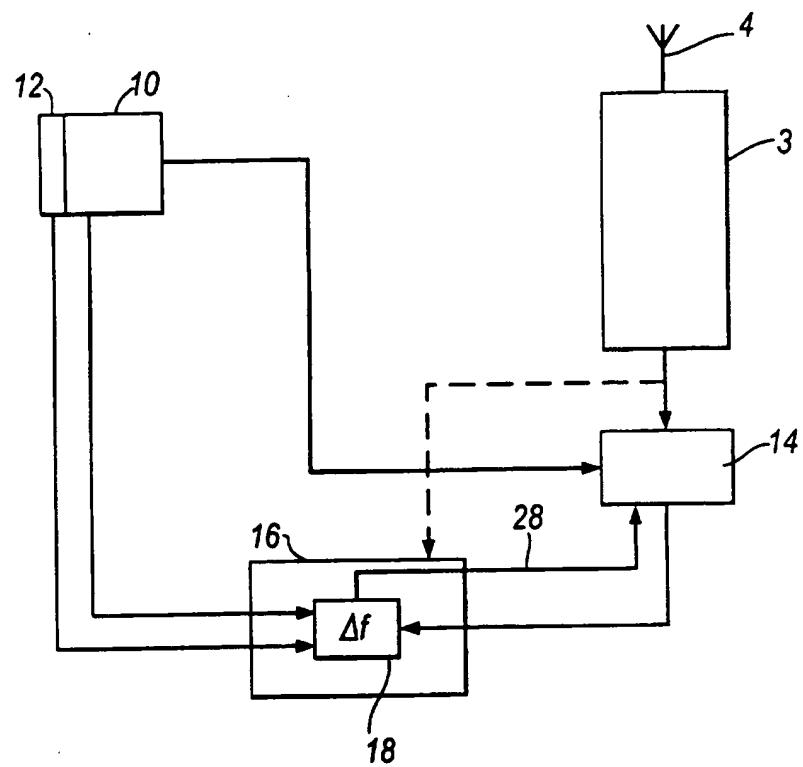
Fig.5

RADIO SYNCHRONISATION SYSTEM

The present invention relates to a radio communication system which serves to provide synchronisation between a radio receiver and a received radio signal. Furthermore, the present invention relates to a method for providing synchronisation between a radio receiver and a received radio signal.

The term radio receiver as used herein includes *inter alia* cellular radio terminals.

In order for a radio communication system to operate, it must first synchronise its receiver to the received radio signal and maintain synchronisation throughout the period of operation. The synchronisation can be achieved via the received signals carrier phase and frequency or for symbol timing. Regardless of which parameter is used for synchronisation, it is assumed that the received signal was transmitted with the same accuracy as that of the system frequency reference signal. This assumption of accuracy is necessary in order for the receiver to demodulate efficiently and where necessary to re-transmit at the correct frequency without relying on the fundamental accuracy of a local frequency reference signal.

The synchronisation process employed by the receiver to synchronise to the received signal will have a defined bandwidth over which said synchronisation is possible. This bandwidth will have a range of parameters, typically frequency or timing, over which detection of a transmitted radio signal is likely, whereas outside this range, the probability of detection is low. The synchronisation process itself will include an algorithm, which may take many.forms, including correlation and matched filtering.

In some situations, the accuracy of a local frequency reference signal is insufficient such that the received signal is outside the synchronisation process

bandwidth. Temperature variation is the dominant, but not sole, cause of frequency inaccuracy. When this occurs, the radio receiver must either employ a plurality of synchronisation processes in parallel, or it must operate a plurality of synchronisation processes serially. Neither technique is desirable due to the increased complexity and increased power consumption for the former solution, and increased acquisition time in the latter solution.

Several methods are currently employed to mitigate this problem. These include the use of a self-contained accurate local frequency reference means such as a temperature compensated crystal oscillator (TCXO) or an oven controlled crystal oscillator (OCXO), to generate a local frequency reference signal. Both oscillators require an active component which serves to control the temperature.

There are several disadvantages of using either of the above mentioned oscillators in a radio synchronisation processes. Both methods add additional cost and physical size to the radio communication system. Additionally, the accuracy of crystal oscillators degrades with time, thus adversely affecting the efficiency of the synchronisation processes.

A technical problem of compensating for inaccuracies in the local frequency reference signal due to both temperature variations and ageing, which has the effect of improving the process of synchronising a radio receiver to a radio signal, is addressed by the radio synchronisation system according to the present invention. Additionally, the present invention offers the advantage of reducing the cost and size of the radio communication system.

Additionally, the present invention will benefit other aspects of radio communication systems which require an accurate local frequency reference signal for optimum operation, such as demodulation and transmission processes.

The invention proposed here employs a different method of compensation for local frequency reference signal inaccuracies caused by, but not limited to, temperature variation and crystal oscillator ageing.

According to the present invention, there is provided a radio synchronisation system for synchronising a radio receiver with a received radio signal, said radio synchronisation system comprising of a radio transmitter arranged to transmit radio signals, a radio receiver arranged to receive said transmitted radio signals, means for providing an accurate system frequency reference signal to which said received signal is assumed to be substantially accurate with respect to its frequency, means for providing a local frequency reference signal which is arranged to provide an initial frequency reference signal to which said radio receiver is initially synchronised, means for executing a synchronisation process by which said radio receiver is synchronised to said received radio signal, characterised in that said radio synchronisation system further comprises of a temperature sensing means disposed proximate said means for providing a local frequency reference signal in a manner such that said temperature sensing means can measure the temperature of said means for providing a local frequency reference signal, whereupon sensing said temperature of said means for providing a local frequency reference signal, said temperature is made available to a signal processing unit which is located proximate said radio receiver and which is arranged to facilitate synchronisation of said radio receiver to said received radio signal by causing initiation of said synchronisation process from an optimum point.

According to a further aspect of the present invention, said signal processing unit maintains a mathematical model of local frequency reference signal variation with respect to temperature change, which when consulted during said

synchronisation process, gives an indication of said optimum point from which synchronisation should be initiated.

According to yet a further aspect of the present invention, said mathematical model is updated during said synchronisation process.

According to yet a further aspect of the present invention there is provided a method for synchronising a radio receiver with a received radio signal, said method comprising the steps of: transmitting a radio signal from a radio transmitter, causing a radio receiver to receive said transmitted radio signal, providing an accurate system frequency reference signal to which said received signal is assumed to be substantially accurate with respect to its frequency, providing a local frequency reference means which is arranged to provide an initial frequency reference signal to which said radio receiver is initially synchronised, initiating a synchronisation process in which said received radio signal is synchronised to said radio receiver, characterised by the further steps of: disposing a temperature sensing means proximate said local frequency reference means in a manner such that said temperature sensing means can measure the temperature of said local frequency reference means, determining of said temperature of said local frequency reference means, making available said temperature information to a signal processing unit, and arranging said signal processing unit to use said temperature information to facilitate synchronisation of said radio receiver to said received radio signal by causing initiation of said synchronisation process from an optimum point.

The present invention offers several potential advantages over the prior art for radio synchronisation systems. Reduced cost, reduced physical size, and lower power consumption are possible with the present invention due to the elimination of the need to control the temperature of the local frequency reference means,

which may be a crystal oscillator. In addition, having and updating a model which predicts the effect a change in temperature has on the frequency generated by the crystal oscillator, and using this information during the synchronisation process will advantageously improve the efficiency in which synchronisation is achieved.

Yet a further advantage of the present invention is the ability to compensate for inacurracies in the local frequency reference means due to ageing of the crystal oscillator.

While the principal advantages and features of the invention have been described above, a greater understanding and appreciation of the invention may be obtained by referring to the drawings and detailed description of the preferred embodiment, presented by way of example only, in which;

FIGURE 1 shows a general schematic view of a radio communication system,

FIGURE 2 is a diagram showing the main features of the radio synchronisation system,

FIGURE 3 is a curve showing a hypothetical relationship between frequency offset and temperature change,

FIGURE 4 shows a block diagram depicting an analogue approach of correcting for frequency offset,

FIGURE 5 shows a block diagram depicting a digital approach of correcting for frequency offset.

Figure 1 provides a general schematic illustration of a radio communication system, which is one application of the radio synchronisation system described by the present invention. In Figure 1, a radio transmission tower 1 is shown to be transmitting radio signals 2 at a frequency which is known to a substantially high degree of accuracy, as required for system operation. The transmitted radio signal

2 is received by a radio receiver unit 3 via an antenna 4 which is disposed on the radio receiver unit 3. The radio receiver unit 3 contains a local frequency reference means 5, which in this preferred embodiment, is a crystal oscillator, for the purpose of generating a local frequency reference signal to be used to achieve synchronisation of the radio receiver unit 3 with the transmitted radio signal 2. The frequency of the local frequency reference signal is known to a substantially less accuracy than the frequency of the transmitted radio signal.

Figure 2 shows a diagram depicting the main components of the radio synchronisation system, where parts also appearing in Figure 1 bear identical numerical designation. In Figure 2 a radio receiver unit 3 with an antenna 4 is arranged to receive radio signals 2 transmitted from a radio signal transmission tower 1. The transmitted radio signal 2 is of a frequency which is known to a very high degree of accuracy, which is determined by the system frequency reference means (not shown). Disposed proximate to the radio receiver unit 3 is a local frequency reference means 10 which generates a local frequency reference signal in the region of, but with substantially less accuracy than, the frequency of the system frequency reference signal. In this preferred embodiment of the present invention, said local frequency reference means 10 is a crystal oscillator type which is left substantially uncontrolled with respect to its temperature. The local frequency reference means 10 is arranged to communicate with an acquisition and synchronisation circuitry unit 14 and with a signal processing unit 16. The acquisition and synchronisation unit 14 is arranged to communicate with the radio receiver unit 3 and with the signal processing unit 16. Located proximate the local frequency reference means 10 is a temperature sensing means 12, which is arranged to measure the temperature of the local frequency reference means and communicate this temperature to the signal processing unit. In this preferred

embodiment of the present invention, said temperature sensing means 12 is a thermocouple type. Located within the signal processing unit is a mathematical model 18 of frequency offset with respect to temperature change which may be pre-programmed into the system during manufacture. In this preferred embodiment of the present invention, said mathematical model 18 is a look up table of coefficients for a polynomial fit of frequency offset with respect to temperature. Prior to attempting to synchronise the radio receiver unit 3 to the transmitted radio signal 2, the temperature sensing means 12 will measure the temperature of the local frequency reference means 10 and communicate this temperature to the signal processing unit 16, which will in turn consult the mathematical model 18 for the correct amount of frequency offset for the corresponding temperature. The frequency offset information will be used to improve the synchronisation process, by either adjusting the local frequency reference means 10 to correct for the temperature related frequency offset, or to communicate this offset to the acquisition and synchronisation unit 14 which in turn will modify a synchronisation algorithm in a manner such that synchronisation will be initiated for an optimum point.

In an alternative embodiment of the present invention, said signal processing unit 16 containing said mathematical model 18 is located in the baseband processing part of said radio receiver unit 3.

In Figure 3, a curve 20 is shown, which represents a hypothetical relationship of frequency offset with respect to change in temperature. In Figure 3 temperature is represented by the horizontal axis 22 and frequency offset by the vertical axis 24. Such a relationship would form the basis of the mathematical model of frequency offset with respect to temperature change. By way of example only, Figure 3 shows that a measured temperature of T 26 would have a frequency

offset of Δf 28. This information would then be used by the mathematical model during the synchronisation process.

It is well known within the art that the frequency generated by a crystal oscillator will change as the crystal oscillator ages. Additionally, in any given batch of crystal oscillators, the frequency generated will vary within a predefined manufacturing tolerance. This manufacturing tolerance for frequency will be substantially less than the accuracy of the system frequency reference signal. Additionally, the temperature sensing means 12 may, due to ageing or other causes, vary in its responsivity.

As a further embodiment of the present invention, the synchronisation process could further operate to compare the actual frequency at which synchronisation occurs to the frequency at which the mathematical model 18 predicts synchronisation should occur for a particular temperature as determined by the temperature sensing means 12.

This comparison could be used to update the mathematical model to account for any changes in the relationship between the frequency offset with respect to temperature, due to crystal oscillator or temperature sensing means ageing, or due to any batch variations.

By updating the mathematical model 18 after each instance of the synchronisation process, an ongoing monitoring of and correction for component degradation is achieved.

As yet a further embodiment of the present invention, this information resulting from the above mentioned comparison could be made available to other processes within a radio communication system, such as demodulation and transmission functions, which require an accurate knowledge of the local

frequency reference, thereby enabling said other processes to account for any offset in the local frequency reference.

In Figure 4, in which parts also appearing in Figures 1 - 3 bear identical numerical designation, an analogue approach of correcting for frequency offset is depicted with Δf 28 being communicated in the form of an analogue voltage to the local frequency reference means 10 which in turn adjusts itself by an amount equal to Δf. The local frequency reference means 10 then generates a corrected local frequency reference signal which is communicated to the acquisition and synchronisation unit 14 for use in the synchronisation process.

In Figure 5, in which parts also appearing in Figures 1 - 4 bear identical numerical designation, an alternative embodiment of the present invention is shown in which a digital approach of correcting for frequency offset is depicted, with Δf 28 being communicated in digital format to the acquisition and synchronisation unit 14, which in turn adjusts a synchronisation algorithm and other radio communication system processes to account for the frequency offset.

As a further embodiment of the present invention, a calibration process could be used during the manufacturing of the radio synchronisation system. This calibration process could involve the characterisation of the local frequency reference means 10 and temperature sensing means 12 during manufacture. This characterisation could then form the basis of the mathematical model and serve to correct for any variations in the local frequency reference signal as generated by the local frequency reference means 10 and/or the temperature sensing means 12. The mathematical model could then be pre-programmed into the radio receiver.

Initial development of the mathematical model would require measuring the frequency of the local frequency reference means 10 at a range of temperatures in which the radio receiver might be required to operate. After establishment of the

mathematical model, it would be possible to calibrate each unit by measuring the frequency of the local reference frequency means at one or more temperatures, thus reducing the time it takes to calibrate each unit.

As a further embodiment of the present invention, there is a method for synchronising a radio receiver unit to a received radio signal. This method involves transmission of a radio signal from a radio transmitter. The frequency of the transmitted signal is known to a substantially high degree of accuracy as determined by the system frequency reference signal. The method further operates to cause a radio receiver unit to receive the transmitted radio signal. Prior to and during the operation of receiving a radio signal, a synchronisation process occurs in which a local frequency signal is generated. This signal is used to establish initial synchronisation of the radio receiver to the received radio signal. The method further provides for a temperature sensing means to measure the temperature of the local frequency reference means and to use this information to improve the synchronisation process. The method provides for this information to be stored in the form of a mathematical model which is developed during the manufacture of the device, and which is stored within the signal processing part of the device. The method further provides for the information obtained from the temperature sensing means and from the mathematical model to be used to compensate for frequency offsets due to temperature changes, and/or changes in the characteristics of various components within the device due to ageing or other factors. The method further provides for the mathematical model to be updated with information obtained during the synchronisation process, thereby further improving the synchronisation process.

As will be appreciated by those skilled in the art, various modifications may be made to the embodiment hereinbefore described without departing from the scope of the present invention.

CLAIMS

1.   A radio synchronisation system for synchronising a radio receiver with a received radio signal, said radio synchronisation system comprising of a radio transmitter arranged to transmit radio signals, a radio receiver arranged to receive said transmitted radio signals, means for providing an accurate system frequency reference signal to which said received signal is assumed to be substantially accurate with respect to its frequency, means for providing a local frequency reference signal which is arranged to provide an initial frequency reference signal to which said radio receiver is initially synchronised, means for executing a synchronisation process by which said radio receiver is synchronised to said received radio signal,

     characterised in that said radio synchronisation system further comprises of a temperature sensing means disposed proximate said means for providing a local frequency reference signal in a manner such that said temperature sensing means can measure the temperature of said means for providing a local frequency reference signal, whereupon sensing said temperature of said means for providing a local frequency reference signal, said temperature is made available to a signal processing unit which is located proximate said radio receiver and which is arranged to facilitate synchronisation of said radio receiver to said received radio signal by causing initiation of said synchronisation process from an optimum point.

2.   A radio synchronisation system as claimed in Claim 1, wherein said signal processing unit maintains a mathematical model of local frequency reference signal variation with respect to temperature change, which when consulted during

said synchronisation process, gives an indication of said optimum point from which synchronisation should be initiated.

3.   A radio synchronisation system as claimed in Claim 2, wherein said mathematical model is maintained in a baseband processing part of said signal processing unit.

4.   A radio synchronisation system as claimed in Claim 2 or 3, wherein said mathematical model is stored as a look up table of coefficients for a polynomial fit of frequency offset with respect to temperature.

5.   A radio synchronisation system as claimed in any of the preceding Claims, wherein said means for providing a local frequency reference signal is of a crystal oscillator type.

6.   A radio synchronisation system as claimed in any of the preceding Claims, wherein said temperature sensing means is of a thermocouple type.

7.   A radio synchronisation system as claimed in any of the preceding Claims, wherein said synchronisation process provides a comparison of frequencies between said local frequency reference signal at which synchronisation was achieved and said local frequency reference signal as predicted by said mathematical model.

8.   A radio synchronisation system as claimed in Claim 7, wherein said comparison of frequencies is used to update said mathematical model during one or more implementations of said synchronisation process.

9.   A radio synchronisation system as claimed in Claim 7 or 8, wherein said comparison of frequencies is used to compensate for an offset in said local frequency reference signal by adjusting said means for providing said local frequency reference signal accordingly.

10.   A radio synchronisation system as claimed in Claims 7, 8 or 9, wherein said comparison of frequencies is made available to said synchronisation process, thereby enabling said synchronisation process to modify its algorithm accordingly to compensate for any offset in said local frequency reference signal.

11.   A radio synchronisation system as claimed in any of Claims 7-10, wherein said comparison of frequencies is made available to other processes within a radio communication system, such as demodulation and transmission functions, thereby enabling said other processes to compensate accordingly for any offset in said local frequency reference signal.

12.   A radio synchronisation system as claimed in any of Claims 2 - 11, wherein said means for providing a local frequency reference signal and said temperature sensing means are characterised during manufacture thereby facilitating development of said mathematical model.

13. A radio synchronisation system as claimed in Claim 12, wherein said mathematical model is pre-programmed into said radio synchronisation system during manufacture.

14. A radio synchronisation system as claimed in any of the preceding Claims, which includes a means for performing a calibration process, which serves to correct for initial variation in said local frequency reference signal and/or temperature sensing means.

15. A radio synchronisation system as claimed in Claim 14, wherein said calibration process consists of measuring a frequency at one or more temperatures and adjusting said mathematical model accordingly.

16. A method for synchronising a radio receiver with a received radio signal, said method comprising the steps of:

transmitting a radio signal from a radio transmitter,

causing a radio receiver to receive said transmitted radio signal,

providing an accurate system frequency reference signal to which said received signal is assumed to be substantially accurate with respect to its frequency,

providing a local frequency reference means which is arranged to provide an initial frequency reference signal to which said radio receiver is initially synchronised,

initiating a synchronisation process in which said received radio signal is synchronised to said radio receiver,

characterised by the further steps of:

disposing a temperature sensing means proximate said local frequency reference means in a manner such that said temperature sensing means can measure the temperature of said local frequency reference means,

determining of said temperature of said local frequency reference means,

making available said temperature information to a signal processing unit,

and arranging said signal processing unit to use said temperature information to facilitate synchronisation of said radio receiver to said received radio signal by causing initiation of said synchronisation process from an optimum point.

17.   A method of synchronising a radio receiver with a received radio signal as claimed in Claim 16, wherein said method further comprises the step of:

maintaining a mathematical model of local frequency reference signal variation with temperature.

18.   A method of synchronising a radio receiver with a received radio signal as claimed in Claims 16 or 17, wherein said method further comprises the step of:

comparing frequencies between said local frequency reference signal at which synchronisation was achieved and said local frequency reference signal as predicted by said mathematical model.

19.   A method of synchronising a radio receiver with a received radio signal as claimed in Claims 17 or 18, wherein said method further comprises the steps of:

updating said mathematical model during one or more implementations of said synchronisation process.

20.   A method of synchronising a radio receiver with a received radio signal as claimed in Claim 18 or 19, wherein said method further comprises the step of:

utilising said comparison of frequencies to compensate for an inaccurate local frequency reference signal by adjusting said means for providing a local frequency reference signal accordingly.

21.   A method of synchronising a radio receiver with a received radio signal as claimed in Claim 18, 19 or 20, wherein said method further comprises the step of:

making available said comparison of frequencies to said synchronisation process; thereby enabling said synchronisation process to modify its algorithm accordingly to compensate for any offset in said local frequency reference signal.

22.   A method of synchronising a radio receiver with a received radio signal as claimed in any of Claims 18 to 21, wherein said method further comprises the step of:

making available said comparison of frequencies to other processes within a radio communication system, such as demodulation and transmission functions, thereby enabling said other processes to compensate accordingly for any offset in said local frequency reference signal.

23.   A method of synchronising a radio receiver with a received radio signal as claimed in any of Claims 17 to 22, wherein said method further comprises the steps of:

characterising said means for providing a local frequency reference signal and said temperature sensing means during manufacture, thereby facilitating development of said mathematical model,

and pre-programming said mathematical model into said radio synchronisation system.

24.   A method of synchronising a radio receiver with a received radio signal as claimed in Claim 23, wherein said method further comprising the steps of:

measuring said local frequency reference signal at one or more temperatures, and adjusting said mathematical model, thereby facilitating said characterisation of said means for providing a local frequency reference signal and said temperature sensing means.

25.   A radio synchronisation system for synchronising a radio receiver with a received radio signal as hereinbefore described with reference to the accompanying drawings.